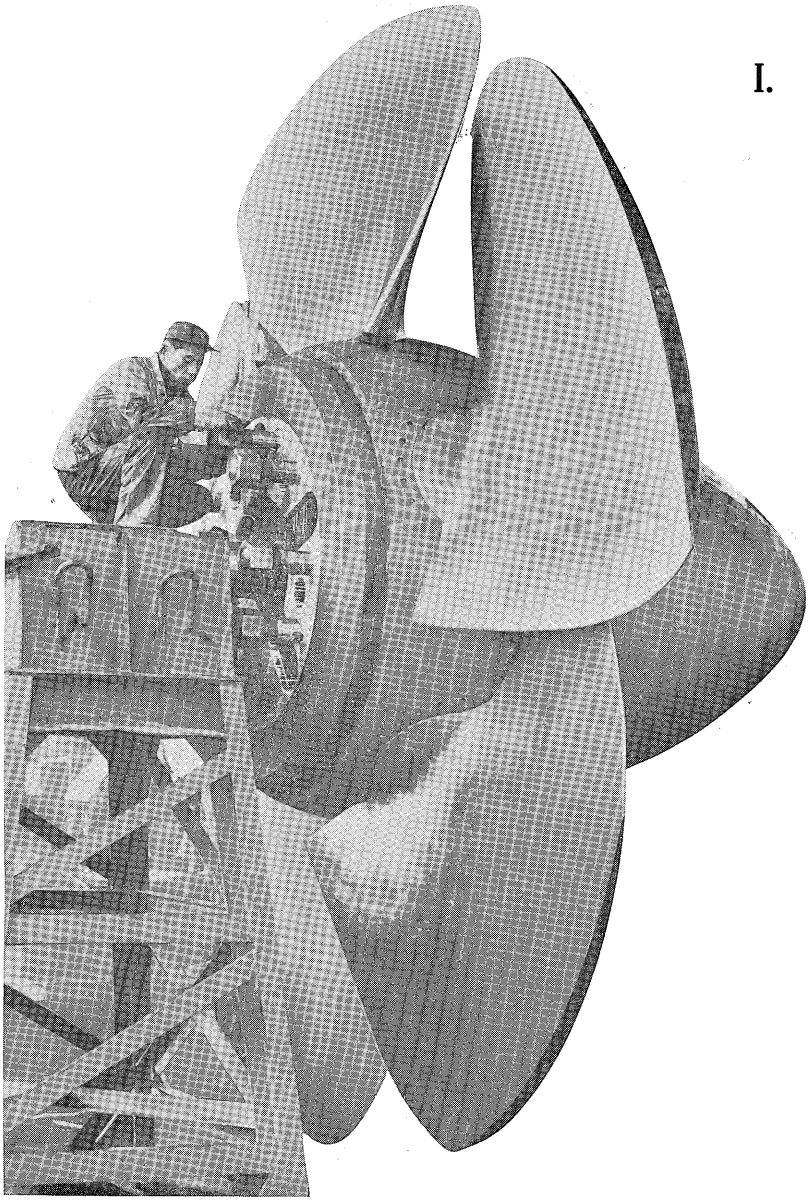

Fig. I·1. Runner of the 10,200 kW Kaplan Turbine at Jintsugawa No. 3 Power Station

I. WATER TURBINES

I·1. HYDRAULIC LABORATORY

The Fuji Electric Manufacturing Company which has an technical contract with J. M. Voith of West Germany is manufacturing water turbines generally in accordance with the basic idea of German enginering, but various technical points of concerning the Kaplan, Francis, or Pelton type turbines are being continually researched and the laboratory tests are being carried at the Company's hydraulic laboratory. Fig. I·2 shows the general view.

The main installation of the laboratory is an efficiency testing set which consists of a model runner of 500 mm dia. with an effective head 3 meters and maximum water flow 700 l/m. A cavitation test apparatus which consists of a model runner of 250 mm dia. with maximum effective head 25 meters makes it possible to test at the maximum flow 350 l/sec. Fig. I·3 shows a part of the cavitation test set.

Special care is taken as to the accuracy of measurement of each of these sets especially the counting of the number of rotations, which often draws attention of engineers visiting the plant. It consists of a counting apparatus of special decatron tube combined with standard watch. The accuracy of the rotation counter may be attained up to $\pm 0.05\%$ and will be sufficient for this sort of apparatus. Fig. I·4 shows its general view. The efficiency of water turbines of various types has lately been brought up to a comparatively high value but the figure obtained as a result of the laboratory test on the model showed 90.5–91.5%. The model under test was a Francis type runner of 500 mm dia. with specific speed 100–260 mkW. The highest efficiency 89.5–90.5% was obtained when the test was made on a Kaplan type runner of 400 mm dia. with number of vanes 4–8.

In the cavitation test, it is usual to measure so-called σ critical point that results in a sudden drops of runner efficiency, but it is also important to investigate cavitation growth phenomena on the part of vane. The model runners in the laboratory either Francis or Kaplan types are made of acrylic

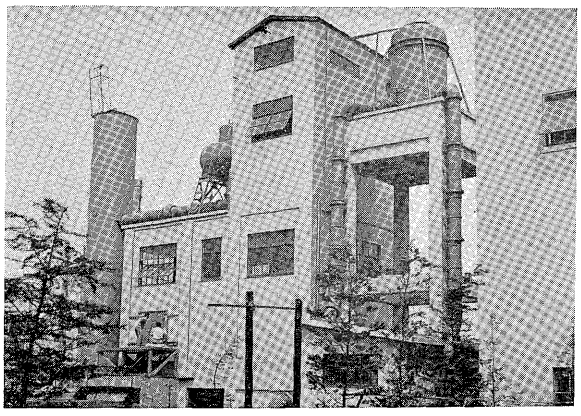

Fig. I·2. General View of the Hydraulic Laboratory

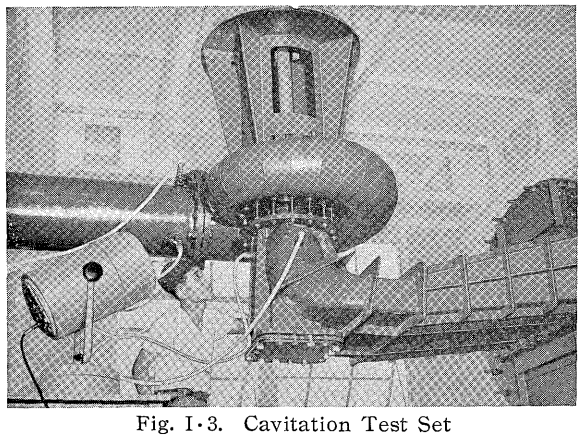

Fig. I·3. Cavitation Test Set

plastic at their peripheral ring, and also all lower covers are made of the same material. This enables the engineers to watch closely all movements of vane parts and make it possible to get proper shape of vane in order to avoid partial cavitations before they get into σ_{Kr}. For instance, engineers were able to make a perfect runner that generates no bubbles at the specific speed $n_s=180$ and $\sigma=0.06$.

I·2 TURBINES OF RECENT MANUFACTURE

The capacity of turbine as well as the number of manufactures at the Fuji Electric Mfg. Co. are rapidly increasing. Table I·1 shows the list of supply since 1954.

Attention may be attracted to the Kaplan turbine of 21,000 kW that was installed at the Jintsugawa No. 2 Power Station of the Hokuriku Electric Power Co., and in addition to that, a 13,000 kW Kaplan turbine for Tsunokawa Power Station of the Kansai Electric Power Co., and a 7,200 kW Kaplan turbine for Horyo Power Station of the Tohoku Electric Power Co., a 10,200 kW Kaplan for Jintsugawa No. 3 Power Station of Hokuriku Electric Power Co., all have gone into operation one after another and are operating in excellent condition. Among the above, the 10,200 kW Kaplan wheel of Jintsugawa Power Station is operating with the basic head 8.22 m and water flow 120 m^3/sec. It is a record for low head Kaplan turbine in Japan that is run with the head less than 10 m. Another Kaplan turbine of 37,000 kW for Akiba No. 2 Power Station of the Electric Power Development Co. is under construction. This turbine, as a single unit, will be the largest Kaplan wheel ever built in Japan.

A Francis turbine of capacity 22,400 kW running at Sudagai Power Station of the Tokyo Electric Co. calls attention as the largest underground power station in Japan. Another Francis turbine of capacity 27,000 kW for Akiba No. 1 Power Station of the Electric Power Development Co. is under construction. The latter plant together with the No. 2 power station

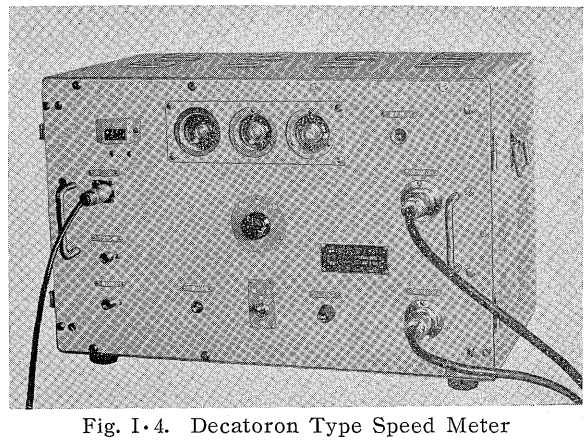

Fig. I·4. Decatoron Type Speed Meter

above described will soon enter into operation as to work reverse regulation of Sakuma Power Station which is well known as the largest hydraulic power plant in Japan. The special feature of Akiba No. 1 Francis turbine is that it is designed to run with the effective head max. 48.8 m and water flow 61.6 m^3/sec and its gigantic mass will match with that of Sakuma turbine.

Among the Pelton type turbines that Fuji Electric Mfg. Co. has built or under construction, those which call attention are the vertical shaft 12,500 kW Pelton turbine of Motosu Power Station of the Nippon Light Metal Co. and also 16,000 kW vertical shaft Pelton turbine for Tochio Power Station of the Hokuriku Electric Power Co.

They are all drawing attension as vertical Pelton wheels for the first time employs in Japan.

Among the machines listed in the annexed table, a few points in regard to their special features will be cited as follows.

The 10,200 kW Kaplan Turbine at Jintsugawa No. 3 Power Station

The capacity of this Kaplan turbine which is designed to run with the head less than 10 m is said to be the largest machine ever built in Japan. Further attention is to be paid to the various new features that have been adopted to the construction

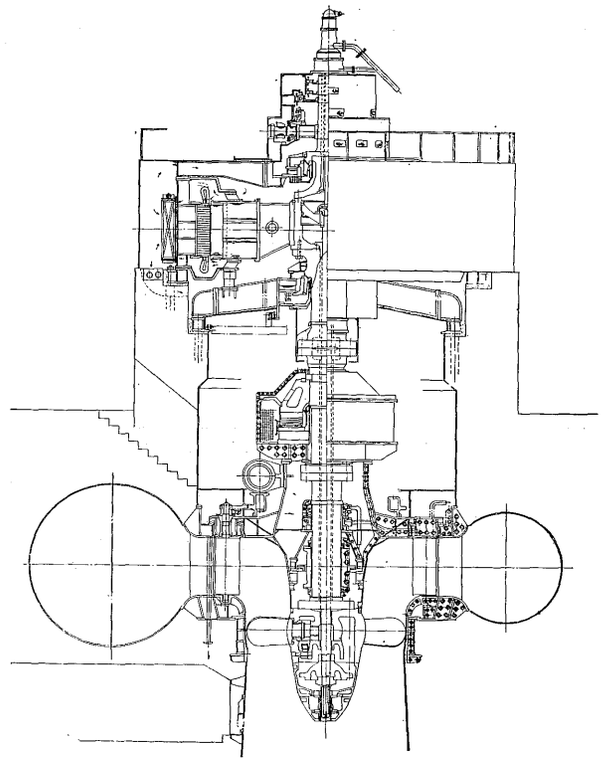

Fig. I·5. Section Drg. of the Turbine and the Generator of Akiba No. 2 P.S.

of this machine. The turbine runner is 4,550 mm in dia. with 5 vanes. Welding construction is extensively adapted to many parts of water wheels, so as to reduce the weight. The runner rings are laid in concrete and each inner surface is reinforced with stainless steel of 18/8 by means of welding. The casing is made of concrete and is of semi spiral construction. The guide vane servomotors are of the ring type. They are located on the turbine upper cover in consideration of that the position of servomotors, if placed on top of concrete casing, may give difficulties to the designe of whole power house.

The runner servomotor is enclosed in the center of generator rotor. The pressure oil supplying devices are not placed on top of generator but so that they will be in common use for the generator guide bearing. The thrust bearing is also located on the turbine upper cover. As a result, the entire construction is made considerablly simple and the height of the power house is made lower. The returning motion of runner vanes are controlled by a special oil pressured returning mechanism which is actuated by a disk plate that is attached to the lower part of the runner servomotor and goes up and down with the piston movement. The speed governor is made in cabinet form but lately, the actuator part of which is replaced by a Fuji's new electric type speed governor which has added a new feature to the machine.

The 22,400 kW Francis Turbine at Sudagai Power Station

This is the first underground power plant built in Japan after the war. It is a turbine of vertical shaft, 2 floor type having an intermediate shaft so that the disassembling of the turbine can be made practicable in the turbine room. Because the plant is located underground, special consideration is being given to the prevention of noise in the machines, the drain of water, the restriction of required floor space, etc. The maximum output of this turbine is 22,400 kW which may be called a comparatively large machine, and yet it is a first attempt that whole machine of this size is manufactured in welded structure. The spiral casing, speed ring, upper and lower cover, bearing and bearing stand, etc.— practically all parts are made by welding. It has greatly saved machine weight and increased reliability on material strength.

The inletvalve is batterfly valve of weight operating type of diameter 2,650 mm. It closes by its own weight with no oil pressure. It assures reliability of valve closing and saves the capacity of oil pressure apparatus.

The 27,000 kW Francis Turbine at Akiba No. 1 Power Station

This is a barrel type vertical shaft turbine and the same as the turbine at Sudagai Power Station, using welded structure as much as possible. The ring type servomotors are largely used on Fuji's Kaplan turbines but here the same servomotors are used on this guide vane. This is the first instance where the servomotors are used on guide vane of Francis type turbine in Japan. The inlet-valve is butterfly valve of weight operating type the same as that of Sudagai Power Station. Fig. I·8 shows the draft tube liner used in this power plant.

The normal effective head of this power plant is 47 m for which the specific speed is taken 265 m-kW. This value goes slightly over the JEC standard but from the result of cavitation test made at full load with $\sigma=0.2$ showed perfectly no bubbles.

The 37,000 kW Kaplan Turbine at Akiba No. 2 Power Station

This will be the record of the largest plant in Japan in its capacity as well as in the effective head of 37 m which is comparatively high for this type.

Here again the turbine main parts are built in welded structure, and there are used ring servomotors, and the thrust bearings located above turbine upper cover, being of the Fuji standard structure. The runner has 7 vanes of 4,080 mm in dia. Fig. I·5 shows the construction in brief.

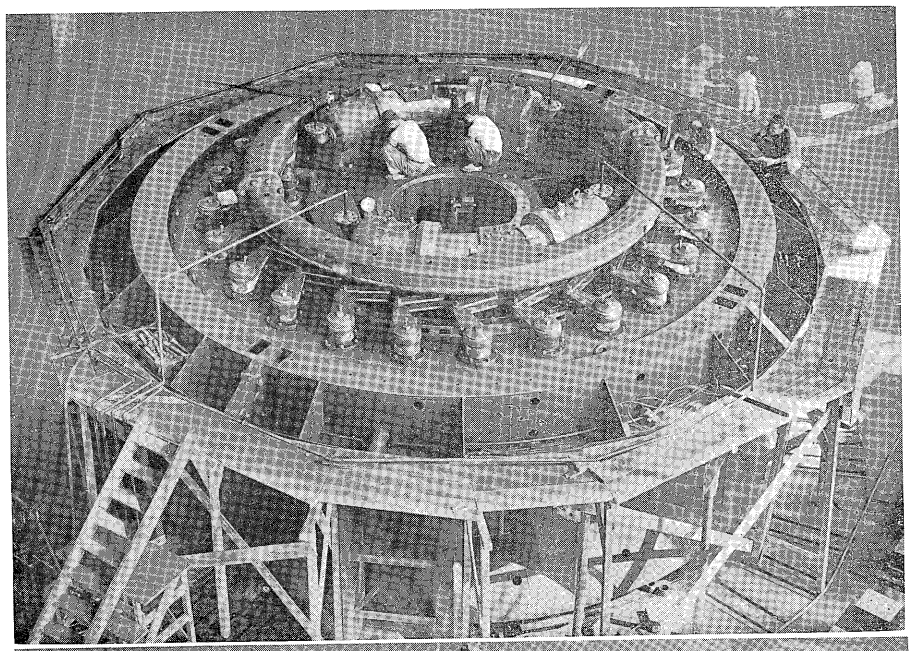

Fig. I·6.
The Kaplan Turbins of
Jintsugawa No. 3 P.S.
in Our Workshop

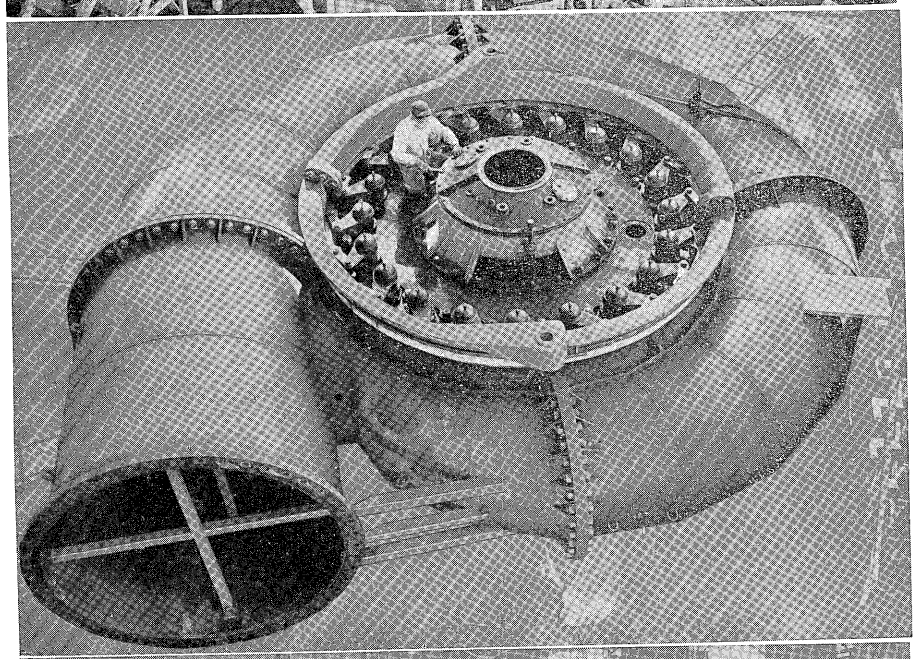

Fig. I·7.
The Francis Turbine of
Sudagai P.S. in
Our Workshop

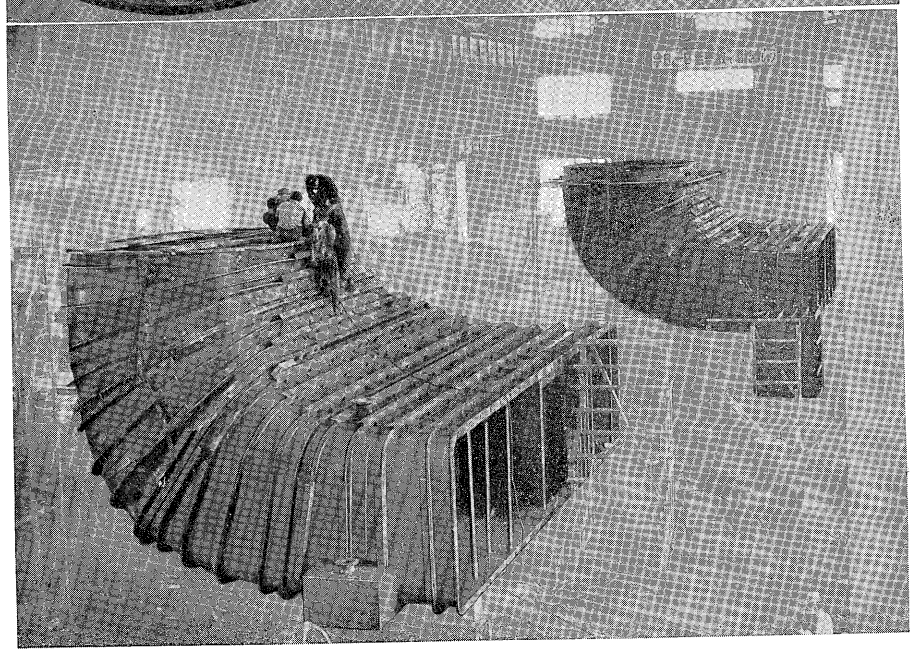

Fig. I·8.
Draft Tubes of
Akiba No. 1. P.S.